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EFFECTS OF PROCESSING VARIABLES ON EROSION OF GUN TUBES

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A reduction in silicon with an associate increase in molybdenum is known to increase the wear life of gun steel when fired under subscale firing conditions. However, when this same material is employed in a full scale firing test utilizing the 105mm M68 gun tube, the wear life of the tube, as measured at the origin of rifling (i.e. OR), remains the same regardless of silicon and molybdenum content. A few inches beyond the OR (27 inches from the rear face of the tube and beyond), the results of the full scale firing test agree with

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the results of the subscale firing tests, in that the low silicon steel exhibits a lower erosion rate than for a normal gun steel composition.

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DEPARTMENT OF THE ARMY
U.S. ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BENET WEAPONS LABORATORY, LCWSL
WATERVLIET ARSENAL, WATERVLIET, N.Y. 12189

DRDAR-LCB-SE

Project No: 6747026

Project Title: Effect of Processing Variables on Erosion of Gun Tubes

Statement of the Problem: This project is the continuation of the work started under Projects 6717026 and 6737026. Under funding for these previous projects, it was found that thermal conductivity was one of the more influential material properties that affected the erosion rate of gun tube material. A small change in thermoconductivity would effect large changes in the erosion rate of steel. To change the thermoconductivity, small incremental changes in composition were made to gun steel material (variations of SAE 4330), with the result that a reduction in silicon content, coupled with a corresponding increase in molybdenum, gave a very favorable change in the rate of erosion. The rate of erosion was measured in all cases under sub-scale firing conditions. The purpose of this project was to apply the results obtained from sub-scale firing, namely, that a low silicon, high molybdenum composition decreased the erosion rate,to a full scale firing test. This was to be done by manufacturing a 105mm M68 gun tube from a low silicon - high molybdenum gun steel, and determining the erosion characteristics of the modified composition during service firing conditions.

Background and Introduction: The service life of certain gun tubes, such as the 105mm M68 and 8" M201, is determined by the rate at which the bore surface erodes. Steel erosion in these gun tubes is a complex phenomenon involving the action of several interrelated processes,[1] namely: (1) chemical reaction of the combustion products with the steel surface, (2) physical interaction of the high-speed stream of combustion products and gases with the bore surface, (3) convective heating of the bore surface by the hot combustion products, and (4) the mechanical

This project was accomplished as part of the US Army Manufacturing Technology program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques and equipment for use in production of Army materiel.

action (i.e. abrasion and swaging) of the moving projectile on the bore surface.

It has been shown by numerous investigators[2,3,4] that variations in the chemical composition of steel influence the erosion rate of steels. Specific findings[5] indicate that reductions in silicon, combined with increases in molybdenum, would, under sub-scale firing conditions, decrease the erosion rate of steel. To substantiate these findings, a full scale firing test was proposed under this project, utilizing the 105mm M68 gun as the test weapon.

Approach to the Problem:

a. Manufacture of an M68 gun tube:

A low silicon - high molybdenum SAE 4335V type steel was obtained for the production of a 105mm M68 gun tube. It had the following composition: .33% C, .23% Mn, .86% Cr, 1.08% Mo, 2.65% Ni, .045% Si, .12% V, .008% S, and .007% P. This material was processed into a gun tube forging which was then rotary forged into the final M68 configuration prior to final machining. Due to a process limitation, only enough material for half a gun tube (the breech half) could be procured. Thus the design for a gun tube extension (the muzzle half) was initiated, with the result that the completed M68 had the first 98 inches RFT (rear face of the tube) composed of the material to be evaluated; while the muzzle end of the tube, 98-210 inches RFT, was normal gun steel[6]. It was felt that the M68 gun tube with extension could be fully evaluated for erosion rates since all wear occurs between the origin of rifling (OR) and 80" RFT. Thus, all erosion that occurred would be in the breech end of the tube, which was composed of the material to be evaluated.

b. Test Plan:

After the gun tube had completed manufacture and assembly at Watervliet Arsenal, it was shipped to Wright-Malta Test Station for firing.

The purpose of the firing was to test the effectiveness of the low silicon - high molybdenum steel in resisting wear and erosion under service conditions. The M490 cartridge, w/o tracer and w/o titanium dioxide liner, was used in the test. Since this cartridge has an erosion rate ten times higher than normal ammunition, it was used for evaluation purposes to get results with the least expenditure of time and money. The rounds were fired in groups of 25 rounds. Firing was stopped when the change in land diameter at the OR (25.25 inches RFT) exceeded the wear condemnation limit of .075 inches.

Before the firing started, the grooves and lands were measured for the length of the gun tube to produce an initial profile. After each group

was fired, the bore was cleaned and inspected. The inspections included the measurement of the land and groove diameters, as well as a visual inspection with the borescope. Several photographs were taken of the bore surface at the OR for each inspection. Muzzle velocity was measured for the first three and the last three rounds of each group.

c. Computer Graphics Program:

A computer program was used to translate the wear data into a graphical presentation depicting the wear profile of a gun tube. The initial measurements taken before firing were used as a baseline for comparison. All measurements taken after firing had the initial bore measurements subtracted from them, so that the plots would show only the net change in diameter due to the wear and erosion of the gun tube.

Results and Discussion:

Results from both a normal gun tube, composition consisting of an SAE 4335V, and the low silicon gun tube, composition consisting of a low silicon - high molybdenum modified SAE 4335 V, are presented in Figure 1 which depicts the wear profile for both tubes after firing 100 rounds with the measurements taken at the 12 o'clock position in the tube.

From Figure 1, one can see that the low silicon gun tube's overall performance was no better than that for the normal gun tube. Both would have reached the condemnation limit of .075 inches after the same number of rounds. At the OR, the wear profile was identical, but once past the OR (beyond 27 inches RFT), there was a measurable difference between the performance of each tube, with the low silicon gun tube showing the least wear. The increase in diameter shown for the region beyond 45 inches RFT was possibly due to a closing down of the bore of the gun tube. This was caused by the thermal compressive stresses due to firing, adding to the already present compressive stresses produced by autofrettage. Together, the resultant compressive stresses exceeded the yield strength of the material. Thus, the material yielded and the tube closed down.

Photographs depicting the progressive erosion of the low silicon gun tube are shown in Figures 2,3,4,5, and 6. Photos were taken of the 12 o'clock portion of the OR after 10, 20, 50, 75 and 100 rounds, respectively, were fired.

The muzzle velocity measurements ranged from 3,853 ft. per sec. to 3,896 ft. per sec. with no decrease in velocity observed between the first round and the last round fired. This indicates that the rounds constantly performed without undue variance throughout the test.

Conclusions:

A reduction in silicon with an associate increase in molybednum is known to increase the wear life of gun steel when fired under sub-scale firing conditions. However, when this same material is employed in a full scale firing test utilizing the 105mm M68 gun tube, the wear life of the tube remains the same regardless of silicon and molybdenum content. This is based upon the fact that the condemnation limit is measured at the OR. A few inches beyond the OR (27 inches RFT and beyond), the results of the full scale firing test agree with the results of the sub-scale firing tests, in that the low silicon steel exhibits a lower erosion rate than for a normal gun steel composition.

Finally, a reduction in silicon with an associate increase in molybdenum for gun steel would not increase the wear life of the 105mm M68 gun tube while firing the non-standard M490 cartridge without tracer and without titanium dioxide liner.

Remarks:

Since low silicon-high molybdenum content gun steel decreases the erosion rate of the M68 gun tube between 27 inches RFT and 56 inches RFT, and since secondary wear which occurs while firing the standard M490 service cartridge also occurs within this same region, it may be hypothesized that a low silicon - high molybdenum content gun steel M68 gun tube would provide a favorable decrease in the erosion rate in the secondary wear zone. At present, a low silicon - high molybdenum content gun steel M68 gun tube is available for firing to test this hypothesis.

REFERENCES

1. Caveny, L. H., Alkidas, A.C., et al., "Steel Erosion Produced by Propellant Combustion Products", Proceedings of the Tri-Service Gun Tube Wear and Erosion Symposium, Ahmad, I. and Picard, J.P., eds., ARRADCOM, Dover, N.J., March 1977.

2. Dieter, G.E. and Rink, J.R., "A Metallurgical Analysis of Erosion in Steel Vents", B.R.L. Report of 941, July 1955.

3. Loeffler, O.H., Phair, G. and Jerabec, H.S., "Metals Tested as Erosion Vent Plugs", NDRC Report A-148, (OSRD No. 1429) Feb. 1943.

4. Kosting, P.R., "Influence of Composition and Heat Treatment of Relative Erosion Resistance of Steel", Watertown Arsenal Lab Mem. Rpt. No. WAL 731/230.

5. Imam, A.R., Final Technical Report #6737026 dated 11 Dec. '75, "Effect of Processing Variables on Erosion of Gun Steel".

6. Campolmi, R., Memorandum for the Record, dated 21 Oct '77, "105mm M68 Gun Tube Extension".

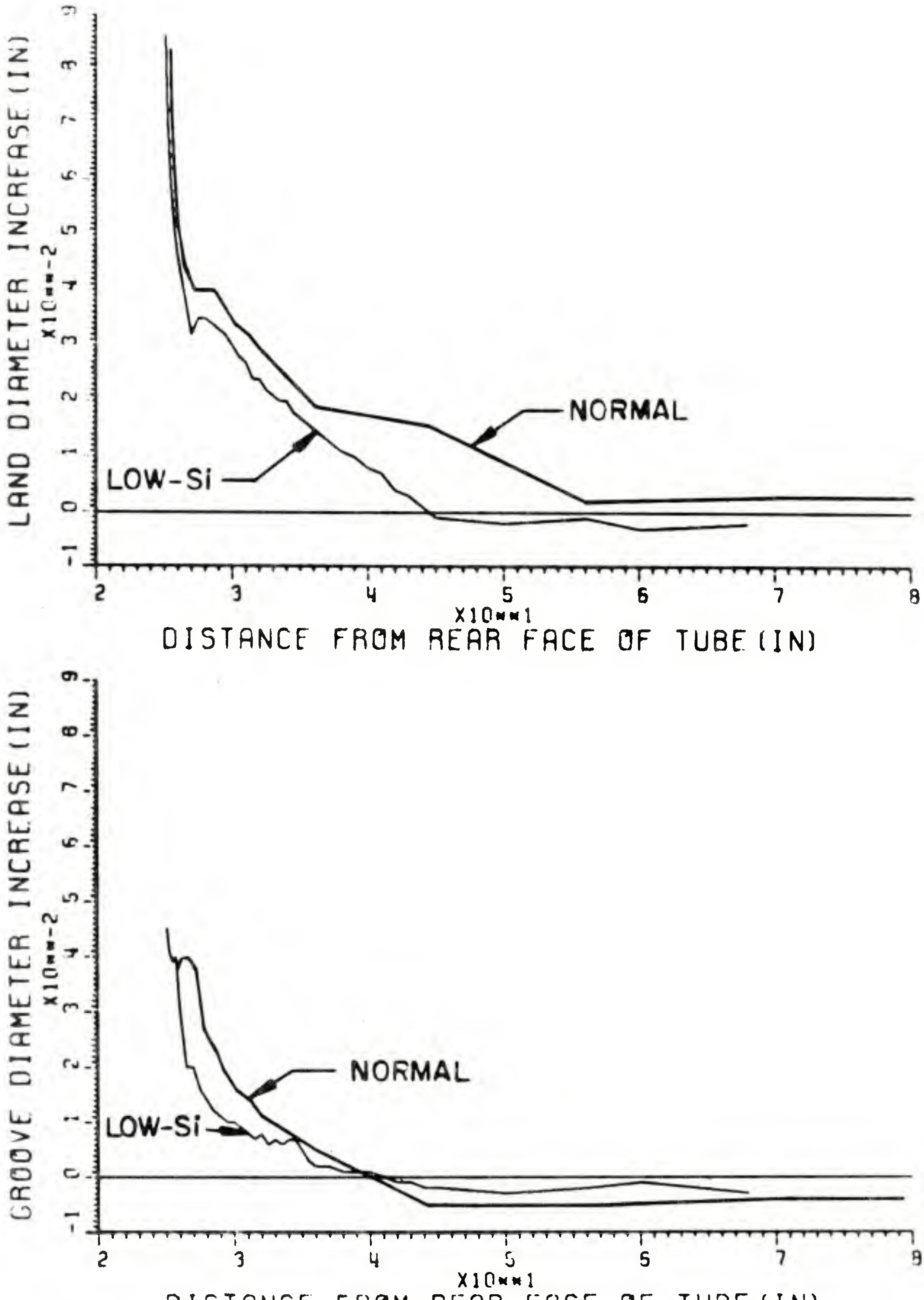

Figure 1. Erosion profiles for normal gun steel and low silicon-high molybdenum gun steel after 100 rounds

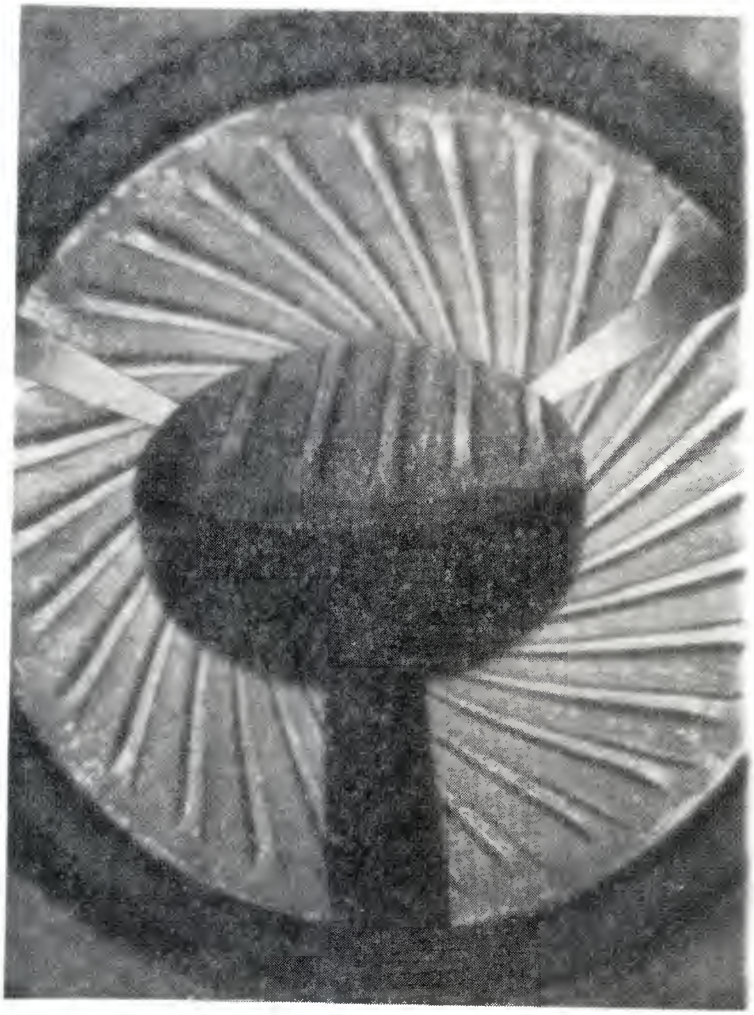

Figure 2. Origin of rifling after 10 rounds

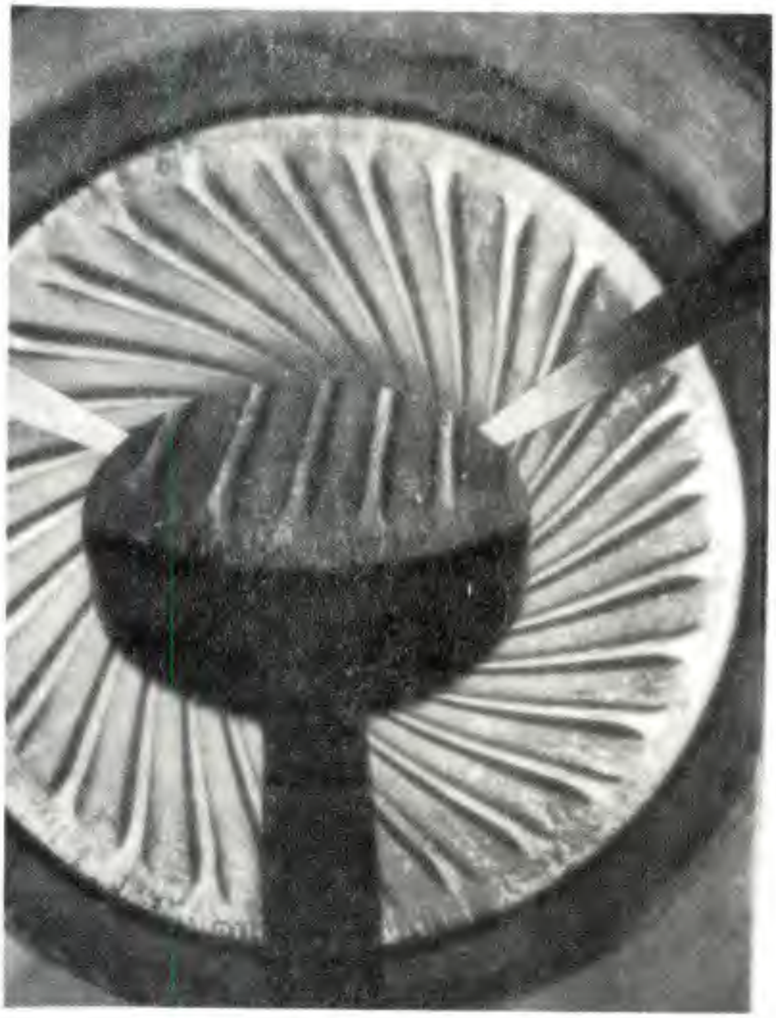

Figure 3. Origin of rifling after 20 rounds

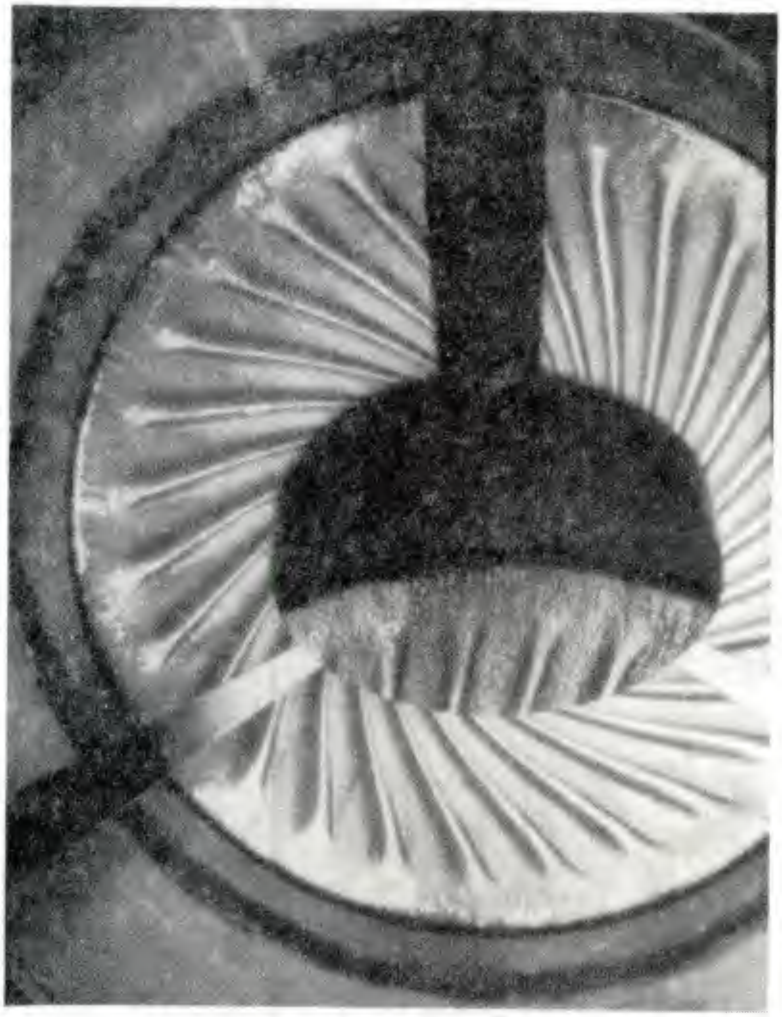

Figure 4. Origin of rifling after 50 rounds

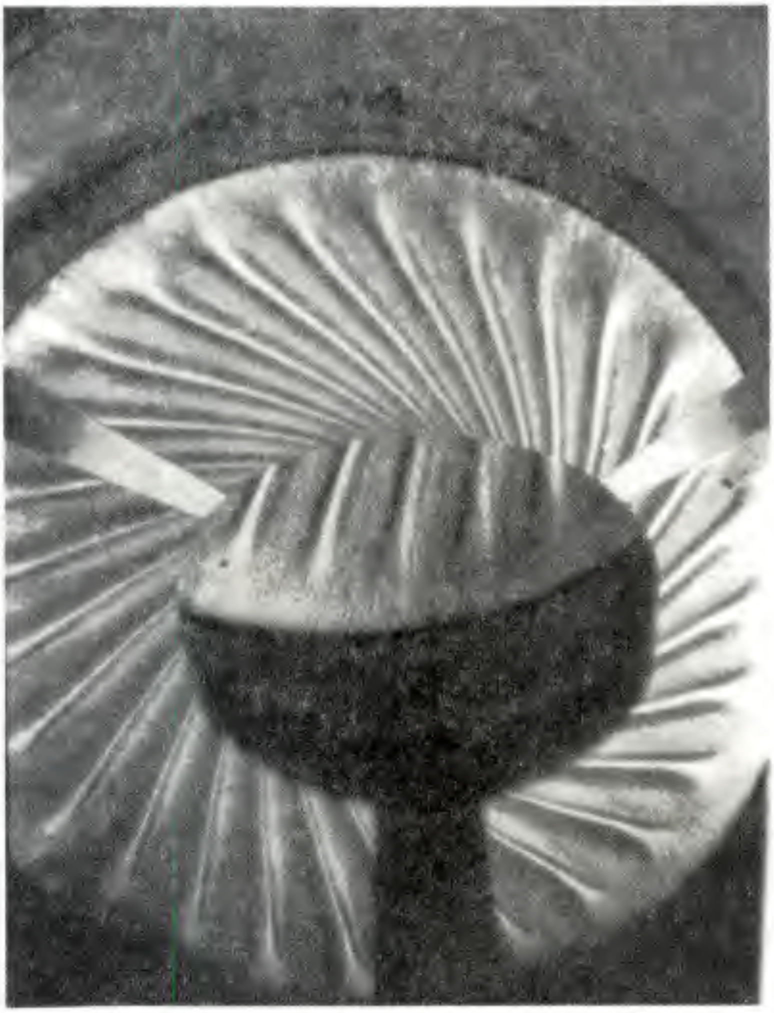

Figure 5. Origin of rifling after 75 rounds

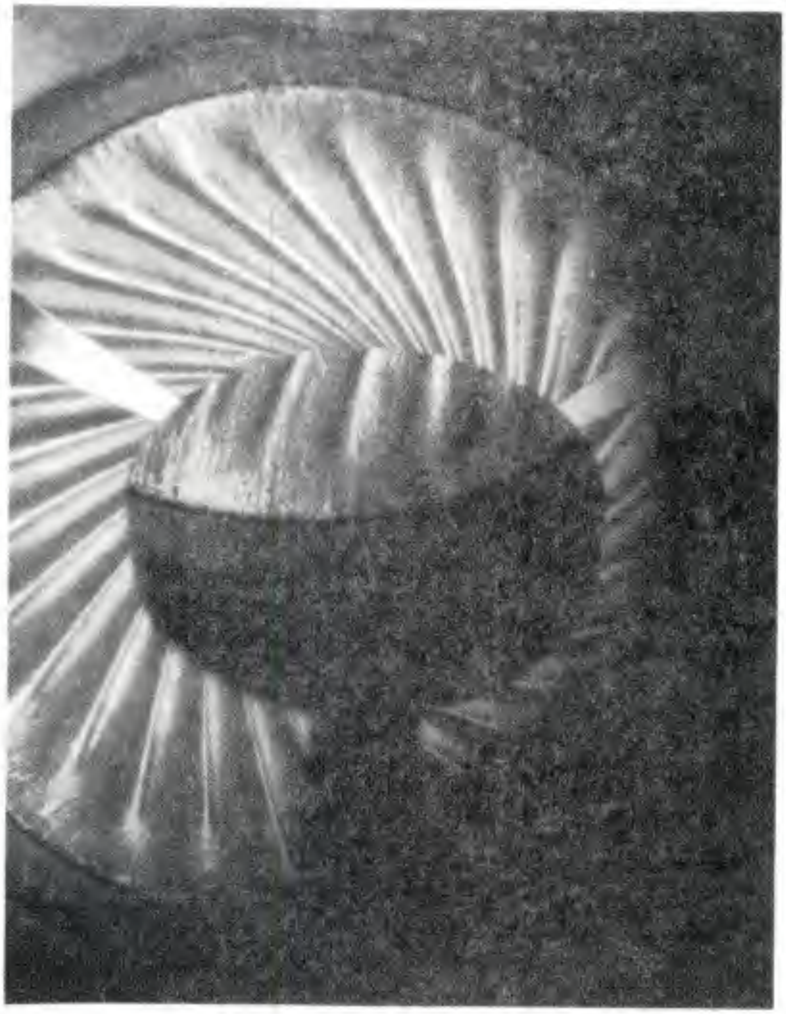

Figure 6. Origin of rifling after 100 rounds

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